# INTERANNUAL VARIABILITY OF THE GIN SEA IN THE 1985-1997 PERIOD MODEL OUTPUTS AND OBSERVATIONS


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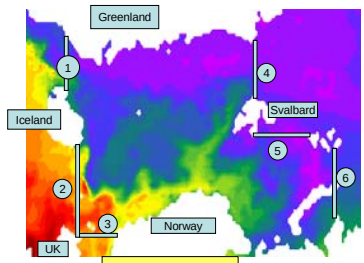
The GIN Sea on the POP Grid




Temp – May 1997

Crossections for Transport Computations

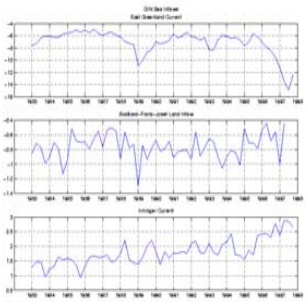
1. Denmark Straits (DMKS)
2. Iceland-Faroe-Shetland Gap (IFSG)
3. North Sea Opening (NSO)
4. Fram Strait (FRAM)
5. Svalbard-FranzJosephLand (SV-FJL)
6. Novaya-Zemlya Straits (NOV-ZEM)

EXCHANGE TRANSPORTS

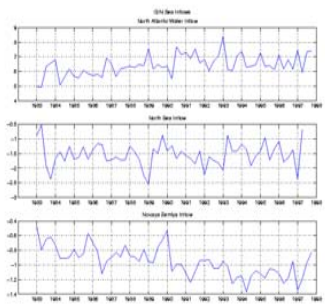
1 – 3: with North Atlantic
4 – 6: with Arctic Ocean

## Introduction

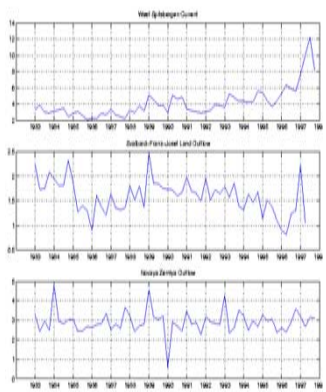
To further understand the origin of the warming episodes of the Arctic Ocean in the last 20 years, attributed mainly due to increased inflows of warmer Atlantic-origin water, we have investigated the changes in the GIN (Greenland-Iceland-Norwegian) Sea from model outputs and hydrographic observations. The GIN Sea serves as the principal passageway between the North Atlantic and the Arctic Ocean, as well as the dominant location of deep water formation feeding the North Atlantic. Large, in-situ hydrographic data sets representing 10 years of measurements, as well as model outputs from a 20-year global simulation have been applied toward evaluating these changes. Interannual variability was computed mainly from changes in the heat content of selected boxes, chosen mostly to overlap (but not limited to) regions of dense data coverage, and from mass and heat transports across the straits connecting the GIN Sea and the Barents Sea to the North Atlantic and the Arctic. A principal component analysis of the mean temperature in the straits was also performed, including Extended EOF's to reveal the structure of decadal variability.



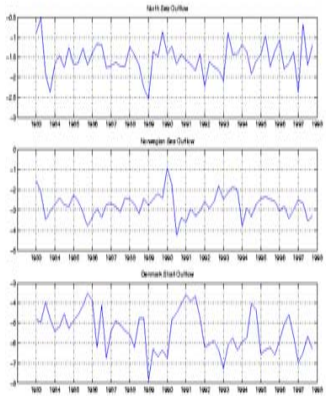
Inflows from the Arctic (Sverdrups):
Top: East Greenland Current
Center: SV-FJL Inflow (from the Arctic)
Bottom: NOV-ZEM Inflow (from the Kara Sea)



Inflows from the North Atlantic (Sverdrups):
Top: IFS Gap Inflow
Center: NS Inflow (from the North Sea)
Bottom: Irminger Current



Outflows into the Arctic:
Top: West Spitsbergen Current
Center: SV-FJL Outflow (from the Barents Sea)
Bottom: NOV-ZEM Outflow (into Kara Sea)



Outflows into the North Atlantic
Top: North Sea Outflow [into NS]
Center: Norwegian Sea Outflow
Bottom: Denmark Strait Outflow

Decadal Behavior of Volume Transports Across 63N, 4W to 6E

| | Average for 1980's | 1990's |
|---|---|---|
| | (in Sverdrups) | |
| NET VOLUME TRANSPORT | **3.33** | **3.86** |
| TRANSP OF AW [T > 3°, S > 34.90] | **2.72** | **3.22** |
| VOLUME OF INFLOW [V > 0] | **4.56** | **5.07** |

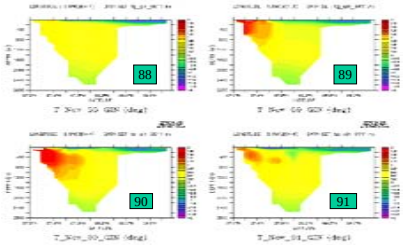
The POP (Parallel Ocean Progam) Model is a z-level (32) model developed at the Los Alamos National Laboratory [Ref. 2].It has been run globally at 1/3 deg resolution, and forced with GCM reanalysis fluxes obtained from ECMWF. The CTD observations were taken by several NATO ships in the area 20W-10E, 60N – 70N, in the years 1986-1993 (except 1990).

Decadal Variability of Northward Flows
Month of February, POP Model

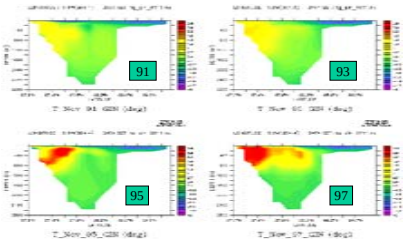
| | T80 | T90 | V80 | V90 |
|---|---|---|---|---|
| | (deg C) | | (SV) | |
| **NAWI** | **6.9** | **7.3** | **6.2** | **7.6** |
| **WSP** | **0.7** | **1.5** | **3.4** | **5.0** |
| **SV-FJL-NVZM** | **0.3** | **0.4** | **3.0** | **3.0** |

Notation:
T80 - mean temperature for the 80's
T90 - mean temperature for the 90's
V80 – mean transport of AW for the 80's
V90 – mean transport of AW for the 90's
NAWI – Incoming AW through the Iceland-Faroe-Shetland gaps
WSP - West Spitsbergen Current
SV_FJL-NVZM - Combined Barents Sea Opening to the Arctic

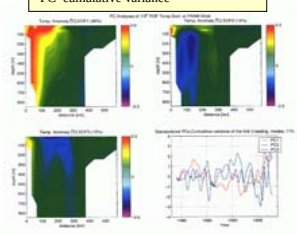
Fram Strait Temperatures, November, 1988-1991



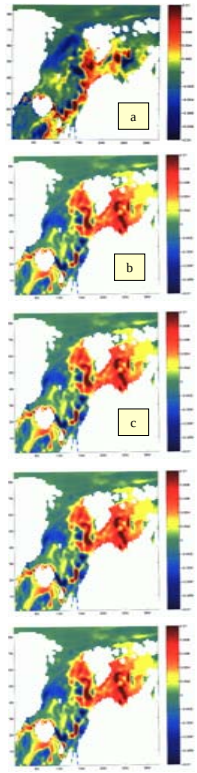

Fram Strait Temperatures, November, 1991-1997



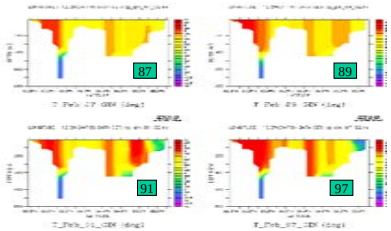

Fram Strait EOF's for Temp Anomalies, PC cumulative variance



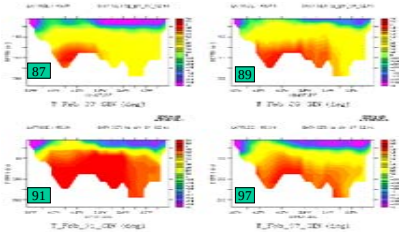
Extended EOF's [EEOF's] for the GIN Sea: 1979-1997 Period [Ref. 2]



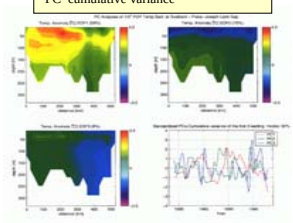

IFS Gap Temperatures, November, 1987-1997



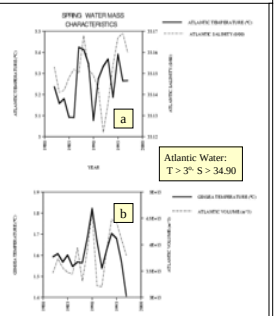

Svalbard-FJL Gap Temperatures, November, 1987-1997




Svalbard-FJL EOF's for Temp Anomalies, PC cumulative variance



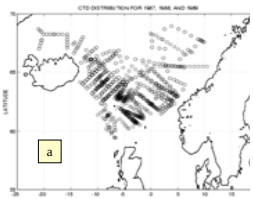
Basin-integrated Changes: 1983-1997




(a) Basin-mean temperature (solid) and salinity (dash) for the AW in the GIN Sea
(b) Total volume (dash) of AW and basin mean temperature (solid) of all water in the GIN Sea

Month of May, 1983–1997 period
POP Model results

Watermass Census from Observations



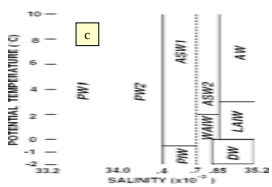

Location of 340 CTD's taken in 5 cruises by the SACLANT Research Center in the June 1987 to October 1989 period [ref. 1]

WATERMASS DISTRIBUTION (PERCENTAGES)
for the individual CTD SURVEYS
[10W - 6E, 60N - 66N]

b

| | C87A Jun | C89A Jun | C87B Sep | C88 Oct | C89B Nov |
|---|---|---|---|---|---|
| PW1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| PW2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PIW | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AW | 30.1 | 34.8 | 40.2 | 14.6 | 14.4 |
| ASW1 | 0.1 | 1.7 | 0.4 | 1.9 | 0.5 |
| ASW2 | 1.1 | 5.5 | 0.7 | 2.5 | 5.1 |
| UAIW | 2.5 | 5.3 | 1.0 | 6.0 | 7.3 |
| LAIW | 10.0 | 25.7 | 13.3 | 10.6 | 11.2 |
| DW | 56.2 | 64.0 | 43.5 | 63.5 | 61.5 |

**Watermass Census for the GIN Sea**
1986-1989 SACLANT cruises
[see (c) for notation]




**Watermass Classification in the GIN Sea:**
AW - Atlantic Water
PW - Polar Water
ASW - Arctic Surface Water
AIW - Arctic Intermediate Water (L-lower), U-upper)
DW - Deep Water

**Construction of EEOF's**: We have constructed a variance-preserving spectra of the spatial average of the depth-integrated (117-600m) temperature of the North Atlantic layer in the GIN Sea and surrounding areas [see Fig. 1]. With the annual cycle removed, we have obtained two significant peaks, at 6.0 and 2.4 years, respectively. The results were then band-passed filtered between 5-9 years and 2-3.8 years. The shorter variability is associated with the Norwegian Current, while the longer one appears to be affecting the overall GIN Sea circulation.

**SUMMARY:** The model results showed that the mean temperature of the GIN Sea has increased significantly from the 80's to the 90's. The basin-mean, depth-integrated temperature has peaked in 1990 and 1995, coinciding with peaks of the total volume of Atlantic origin water (AW). The temperature of the flows through the Fram Strait peaked significantly in the 1990-91 and the 1996-97 periods, exceeding the mean values of the other years by factors of 1.8 and 2.2, respectively. The corresponding periods in the AW inflow at the south do not show such prominent peaks, though there is an overall increase in both the temperature and the inflow volume from the 80's to the 90's.
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Future Work: a) Comparison to current meter and ADCP measurements
b) Quantitative analysis: covariances, rms differences, etc

**References**

1. Perkins,H., T.S.Hopkins, S.-A.Malmberg, P.-M.Poulain and A.Warn-Varnas Oceanographic Conditions east of Iceland. J. Geophys. Res. 103, p.21531, 1998.2.2.
2. White,W., Y.M.Tourre, M.Barlow and M.Dettinger A delayed action oscillator shared by biennial, interannual and decadal signals in the Pacific Basin. J. of Geophys. Res. 108, C3, 3070, 2003.
3. Dukowicz,J. and R.Smith J. of Geophys Res., C, Apr 1994